LOW-LEVEL INVERSION FREQUENCY IN THE CONTIGUOUS UNITED STATES*

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ABSTRACT

A tabulation of percent frequencies of inversion and/or isothermal conditions, based below 500 feet above station elevation, for Weather Bureau radiosonde stations in the contiguous United States for four observation times, provides a sampling of daytime and nighttime stability conditions for all time zones. These data are analyzed with respect to nighttime surface wind speed and cloud cover. Radiosonde data are compared to vertical temperature gradient data obtained from meteorologically instrumented towers and valley-ridge stations. Finally, an attempt is made to delineate, geographically and climatologically, the percent frequency of low-level stability for the entire country.

1. INTRODUCTION

Air pollution surveys of entire industrial regions and metropolitan areas are in demand by public and private agencies for purposes of evaluating levels of air contamination, air zoning regulations, and identification of obnoxious sources. In recent years meteorology has assumed an important role in the atomic energy industry for engineering and operational applications common to the industry generally, but in particular because of its application to the study of dispersion of airborne radioactivity by the atmosphere. Weather may play an important role in either conventional or nuclear industries and the proper appreciation of certain meteorological factors is paramount for an intelligent analysis and evaluation of air pollution phenomena.

In essence the dilution efficiency of the atmosphere depends on the wind and temperature gradients, both of which vary vertically, horizontally, and with time. Since the general spatial problems of slow atmospheric dispersion which affect large areas unquestionably arise at times when a stable stratified layer of air exists near the surface, a knowledge of the frequency of low-level stability for geographical and/or climatological areas will be helpful for assessing the potential for air pollution inherent to a given region. This study involves the compilation of inversion frequencies and the analysis of related meteorological parameters in an attempt to delineate, geographically and climatologically, the percent frequency of low-level stability for the contiguous United States.

2. INVERSION DATA

The initial step for obtaining statistics of inversion occurrence was to select upper air data that most nearly corresponds to daytime and nighttime periods. Table 1 gives the observation times for radiosonde soundings from which vertical temperature gradient data could be obtained. It was decided that a 2-year sampling of both 0300–1500 GMT and 0000–1200 GMT observation periods would be sufficient to give representative frequencies of daytime and nighttime inversion occurrence for each time zone. Accordingly, the National Weather Records Center at Asheville, N.C., tabulated for selected stations a percent frequency of inversions and/or isothermal layers based at or below 500 feet above the station elevation. This level was arbitrarily selected to define a minimum vertical depth of air, and it also permitted convenient tabulation of data from radiosonde sounding plots. These frequencies, given to the nearest whole percent, are based on all observations actually taken for a given time and season (Winter; December, January, February; Spring: March, April, May; etc.). These data are listed in the Appendix.

3. PROCEDURE

Rather than knowing only a percent frequency of inversions for any given observation time, it is desirable to have an estimate of inversion occurrence as a percent of total time sampled (seasonal or annual). Continuous

TABLE 1.—*Radiosonde observation times*

Date	Greenwich	Local standard time: Eastern	Central	Mountain	Pacific
Prior to Apr. 1, 1948	2300	1800	1700	1600	1500
	1100	0600	0500	0400	0300
April 1948–June 1957	0300	2200	2100	2000	1900
	1500	1000	0900	0800	0700
June 1957–present	0000	1900	1800	1700	1600
	1200	0700	0600	0500	0400

*Support for this study was jointly provided by the U.S. Atomic Energy Commission and the U.S. Public Health Service.

TABLE 2.—*Approximate number of nighttime hours (in 24-hour day)*

	Winter	Spring	Summer	Fall
North	15	11	9	13
Central	14	11	10	13
South	13	12	11	12

recording of vertical temperature gradient such as that obtained from towers gives such statistics, but the radiosonde data available do not permit such a tabulation directly. Therefore, to prepare frequencies of low-level stability as a percent of total seasonal hours from radiosonde data, the following hypothesis was used for analyzing data from *inland* stations: The entire nocturnal period was considered stable if an inversion was observed at any time during the night, and the maximum percent frequency of inversions for any one observation time within a nocturnal period was assumed applicable to the entire nighttime period; and, conversely, the entire daytime period was assumed to be unstable, and low values of inversion frequencies occurring at observation times during the daytime heating period were not considered in computation of inversion frequency as a percent of total hours.

A review of table 1 suggests that for the most part daytime observations are made either shortly after sunrise (transition period of stability to instability) or shortly before sunset (instability to stability); consequently, the "daytime" observations are not truly representative of the unstable solar heating period. In general, it is felt that ignoring the low frequency values for daytime observations compensated for the apparent overestimation arrived at from attributing the maximum frequency value to an entire nocturnal period.

A rough determination of length of nighttime periods was made from the Smithsonian Meteorological Tables [9] and resulted in three station categories: (a) the northern tier of States; (b) an area roughly between 30° and 40° N. latitude, comprising the largest number of stations; and (c) the southern regions along the Gulf of Mexico. The number of nighttime hours in each category by seasons is shown in table 2.

TABLE 3.—*Example of inversion percent frequency determination for inland stations*

Bismarck, N. Dak.					
	Maximum percent value (nighttime)	Observation time (LST)	Nighttime period (hours)	Fraction of 24-hour day	Inversion frequency (percent of total hours)
	A			*B*	*A*×*B*
Winter	67	0600	15	$\frac{15}{24}=.625$	67×.625=42
Spring	61	0600	11	$\frac{11}{24}=.458$	61×.458=28
Summer	77	2100 and 0600	9	$\frac{9}{24}=.375$	77×.375=29
Fall	69	2100	13	$\frac{13}{24}=.542$	69×.542=37

The method for computing a percent frequency of low-level stability for inland stations, defined as a percent of total seasonal (annual) hours, is exemplified in table 3, using radiosonde data from Bismarck, N. Dak. The results from this technique were compared to continuously recorded vertical temperature gradient data from towers (discussed later), and appear to be quite adequate for an overall climatological analysis.

In analyzing and computing the inversion frequency data, it became apparent that there was a notable exception to this technique. Inversion frequencies obtained from coastal stations reflect marine influences; that is, in coastal areas low-level stability may be either inhibited or enhanced by advection, in contrast to inland areas that, for the most part, exhibit radiation-type inversions. The coastal regions could be divided into (a) the Atlantic coastal sections of the Southeastern States and the entire coastal region of the Gulf of Mexico, where relatively warm water exists offshore, and (b) coastal sections of New England and the Pacific States where ocean waters are relatively cold. The effects of air-water-land temperature differential and associated land-sea breeze regimes on low-level stability are apparently reflected in the inversion frequency values of many coastal stations that are affected by a frequent flow of air from over the ocean. In general, for coastal areas along the South-

TABLE 4.—*Comparison of coastal and inland inversion frequencies (percent)*

Station		Winter				Spring				Summer				Fall			
Pacific Coast	*LST*	*16*	*19*	*04*	*07*	*16*	*19*	*04*	*07*	*16*	*19*	*04*	*07*	*16*	*19*	*04*	*07*
Oakland, Calif. (coastal)		10	66	77	88	14	23	45	35	34	29	21	13	15	58	62	62
Medford, Oreg. (inland)		16	75	65	70	2	35	74	40	0	13	80	32	6	63	76	73
Tatoosh Island, Wash. (coastal)		17	22	14	15	11	21	18	15	19	31	37	20	29	35	33	38
Seattle, Wash. (inland)		24	13	63	31	0	6	54	30	1	3	57	19	9	19	69	32
Gulf of Mexico	*LST*	*18*	*21*	*06*	*09*	*18*	*21*	*06*	*09*	*18*	*21*	*06*	*09*	*18*	*21*	*06*	*09*
Burrwood, La. (coastal)		46	63	69	36	18	57	51	11	4	26	11	1	13	38	33	3
Lake Charles, La. (inland)		12	61	58	30	3	53	58	5	5	62	71	3	9	75	61	12
Southeastern Atlantic	*LST*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*
Key West, Fla. (marine)		1	2	6	26	1	0	1	4	0	0	1	0	1	0	0	1
Miami, Fla. (coastal)		29	39	60	6	10	27	47	2	21	27	65	2	19	41	75	3
Jacksonville, Fla. (inland)		44	69	59	27	10	53	61	4	11	38	56	1	37	51	76	12
Northeastern and Middle Atlantic	*LST*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*	*19*	*22*	*07*	*10*
Hempstead, L.I., N.Y. (coastal)		18	21	24	7	36	36	32	3	22	45	21	1	24	48	30	1
Lakehurst, N.J. (inland)			41		17		47		2		51		2		59		12
Washington, D.C. (inland)		30	44	48	22	12	42	51	5	5	47	57	2	34	56	59	8

TABLE 5.—*Example of inversion percent frequency determination for coastal stations*

	Representative nighttime value (percent)	LST observation	Night fraction of 24-hour day	Representative daytime value (percent)	LST observation	Day fraction of 24-hour day	Inversion percent frequency for total hours
Miami, Fla.	A		A_1	B		B_1	AA_1+BB_1
Winter	39	2200	0.542	6	1000	0.458	21+3=24
Spring	27	2200	.500	2	1000	.500	14+1=15
Summer	27	2200	.458	2	1000	.542	12+1=13
Fall	41	2200	.500	3	1000	.500	20.5+1.5=22
Oakland, Calif.							
Winter	77	0400	.582	10	1600	.417	45+4=49
Spring	45	0400	.458	14	1600	.542	21+8=29
Summer	21	0400	.417	34	1600	.583	9+20=29
Fall	62	0400	.542	15	1600	.458	34+7=41

eastern States and Gulf of Mexico, a flow from over warm waters tends to inhibit inversion formation at night, while daytime sea breezes exhibit neutral stability. The net result is lower inversion frequency for coastal areas than for inland areas in these regions. The cold waters off the Pacific coast and northeastern Atlantic coast produce cool sea breezes which enhance low-level stability, resulting in higher frequencies of inversions, particularly during daytime hours, for these areas. Examples of these coastal regimes are given in table 4, where a list of inversion frequencies for coastal and nearby inland stations can be compared.

A review of these comparisons suggests that locations only a few miles inland from the coast exhibit a continental-type frequency of low-level stability (e.g., Lake Charles and Jacksonville). Consequently, in analyzing the radiosonde data for stations in coastal areas, it was necessary subjectively to classify by season each station as "inland" or "coastal" according to the marine effects reflected by the frequency data, as well as to consider station proximity to the water and prevailing wind directions. For stations designated coastal, both daytime and nighttime inversion frequency values were considered for computing an inversion frequency as a percent of total hours, instead of neglecting daytime values, as was done for inland stations. An example of attributing both a representative daytime and nighttime percent frequency value to the respective diurnal periods for computing inversion frequencies is shown in table 5 for the coastal cities of Oakland and Miami.

Isopleths of inversion frequency, expressed as a percent of total hours, for the contiguous United States are shown in figure 1 A–E.

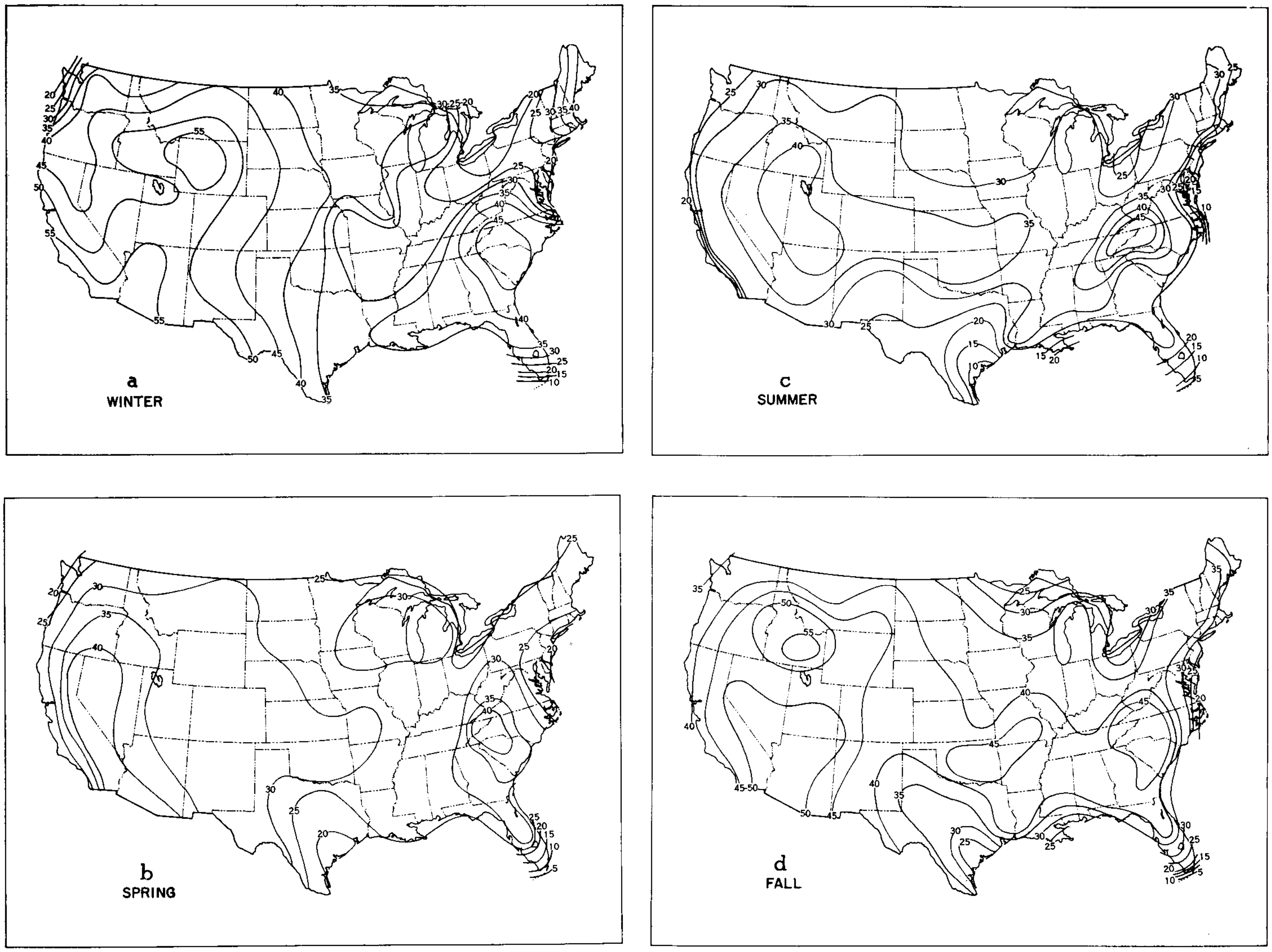
Isopleths of the maximum inversion frequency value reported at any of the four observation times are shown in figure 2 A–E. Conservatively, these values show the percent frequency of nights (or days) that had *at least one hour* of inversion. However, it is reasonable to interpret these statistics to show a percent frequency of nights (or days, for some coastal areas) having several hours of inversions, since an inversion reported at any one hourly observation during the night (or day) implies that such stability will continue (or has continued) for more than one hour if it already exists. This has been shown by analysis of cumulative frequencies of inversions obtained from meteorological tower data [1, 4, 8, 10] at inland sites. Such data for four sites are shown in figure 3. These data are plotted on log-probability scales to enhance the "breaks" in the curves (abrupt changes in probability) which reflect the length of stable nocturnal periods. These analyses of tower data also support the concept used to determine inversion frequency for inland stations as a percent of total time. That is, a percent frequency of inversions at night for any one hour gives a value that is approximately representative for any hour during the nocturnal stable period.

The inherent shortcomings involved in this type of analysis are obvious. The subjectivity in the analytical methods, differences of topography, geography, observation time (relative to the diurnal cycle), and sampling periods are sources of possible error. However, a more exact quantitative assessment of low-level inversion frequency is not easily obtained from existing radiosonde data. It is hoped that this study may provide a means for comparing one section of the country to another, relative to inversion frequency, as well as furnishing information helpful for developing a diffusion climatology of the United States.

4. CLOUD COVER AND LOW WIND SPEED

Meteorologists, from experience, would expect clear skies and light surfaces winds at night to favor the formation of nocturnal radiation-type inversions over land. Cloud cover and wind speed data for available stations, tabulated for a 5-year period in *Summary of Hourly Observations* by the U.S. Weather Bureau were analyzed with respect to the inversion frequency data. These statistics are tabulated in the Appendix.

The inherent subjectivity involved in nighttime observations of cloud cover (e.g., thin cirrus), together with different exposures and elevations of anemometry, restricts any quantitative analysis. However, a statistical study was made of the relationship of nighttime cloud cover and wind speed to inversion frequency, resulting in poor correlation for all seasons. For example, figure 4 indicates a poor relationship, although a trend is evident, of observed maximum inversion frequency to occurrence of nighttime winds (≤ 7 m.p.h.) and nighttime cloud cover



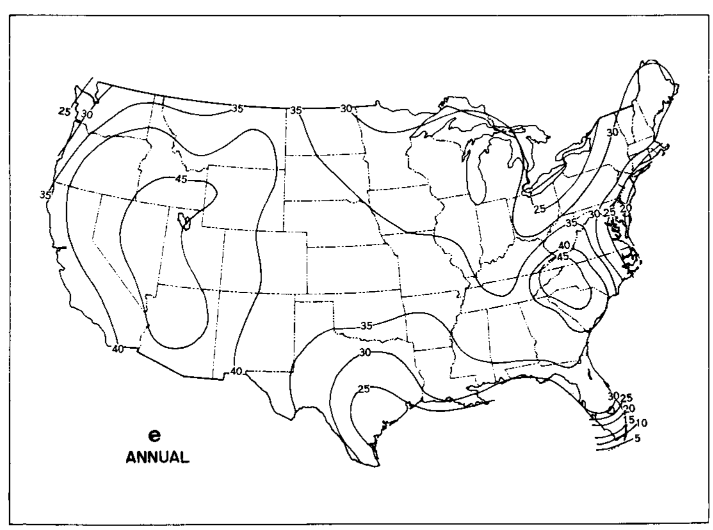
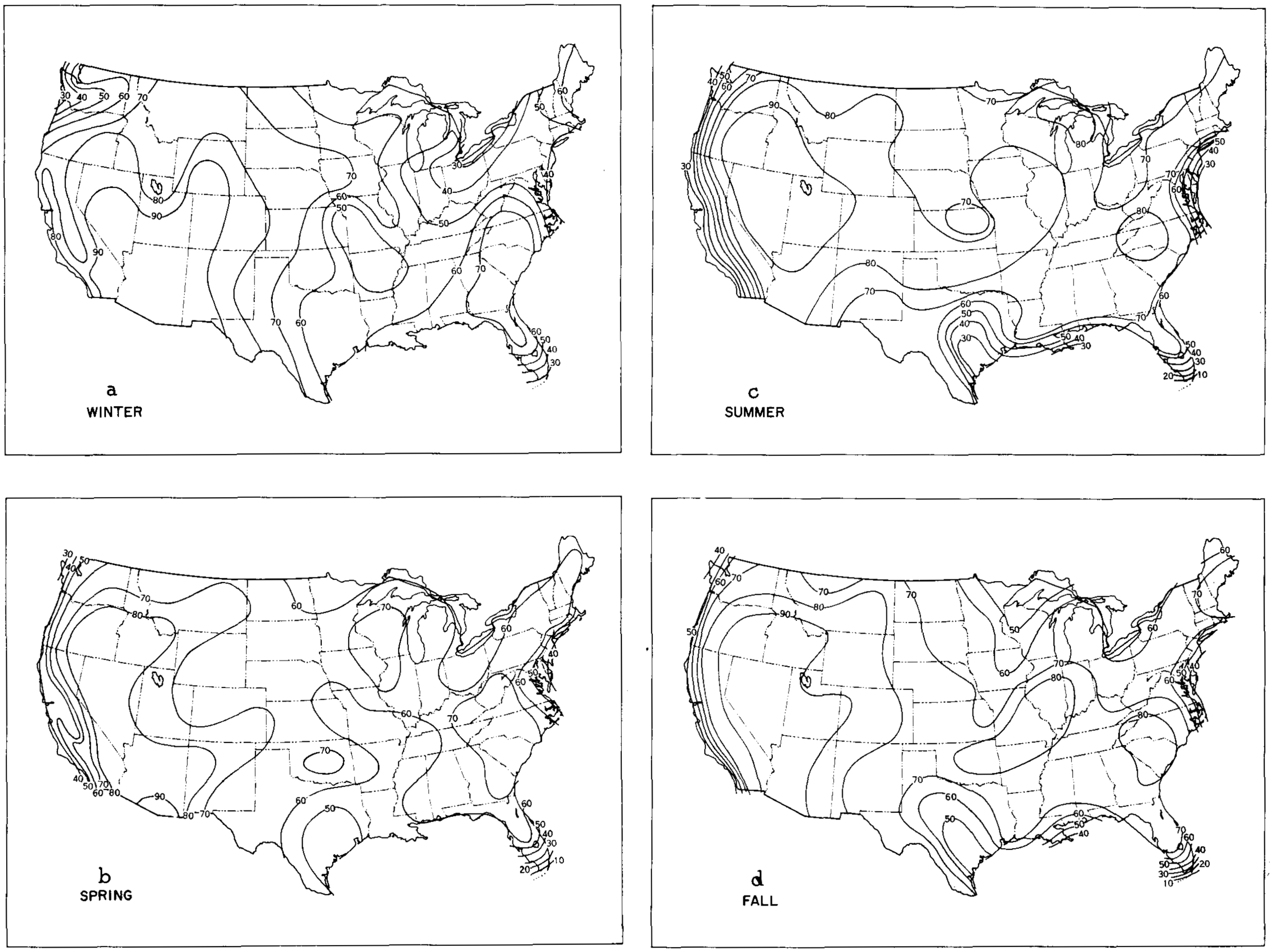


FIGURE 1.—Inversion frequency (percent of total hours): (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.



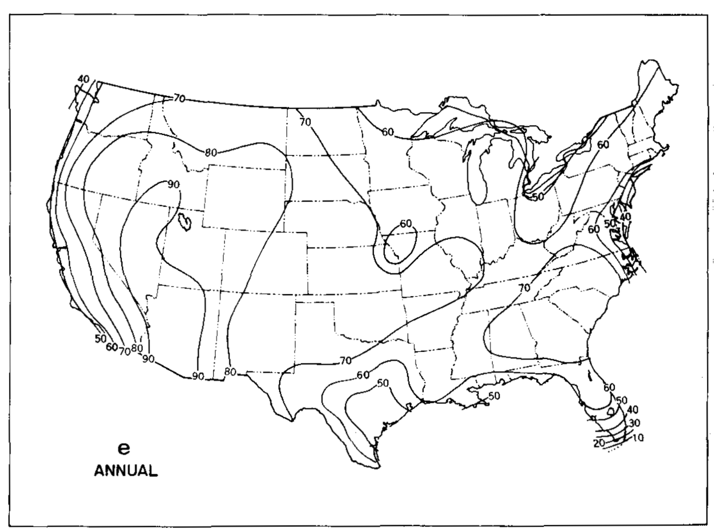


FIGURE 2.—Inversion percent frequency (maximum observed): (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.

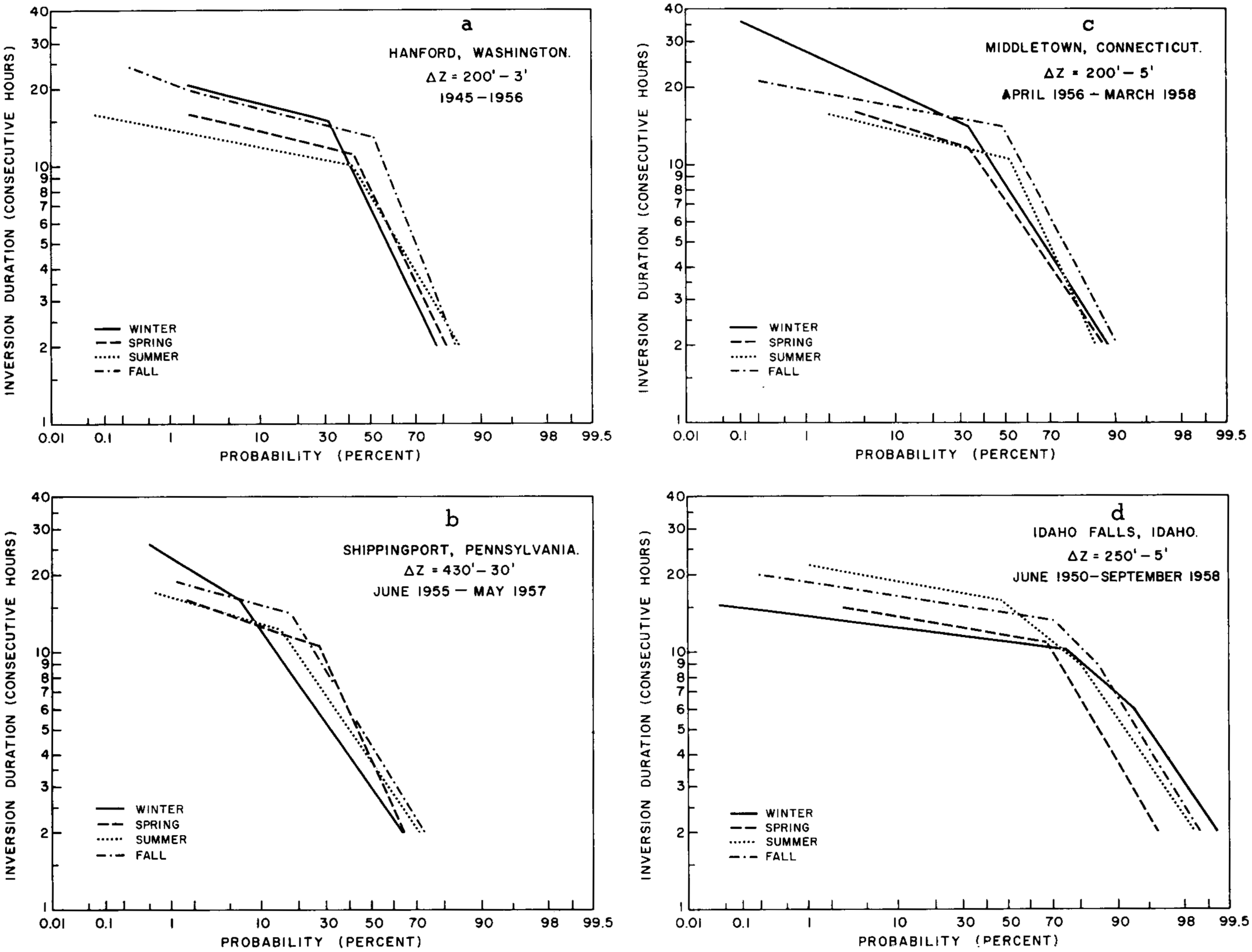


FIGURE 3.—Cumulative percent frequency of inversions from meteorological towers and valley-ridge stations: (A) Hanford, Wash., (B) Shippingport, Pa., (C) Middletown, Conn., and (D) Idaho Falls, Idaho.

($\leq 3/10$) respectively, for winter. Although this indicates that precise frequency values of low-level inversions may not be obtained for a specific location from wind speed and cloud cover data alone, isopleths of percent frequencies of cloud cover and wind speed, shown in figures 5 and 6 respectively, indicate that the general areas having a higher frequency of inversions are also characterized by a higher frequency of relatively clear nights with light winds, and vice versa. This relationship can be further illustrated by graphic addition of the cloud cover and light wind frequency values. The sums of these percent frequencies were divided by 2 to give conventional values within the range of 0–100. These isopleths of nighttime (cloud cover+wind speed)/2 are shown in figure 7.

5. CURRENT OBSERVATION DATA

Since two of the observation times (0300 and 1500 GMT) used in computing inversion frequency are no longer in use, it is desirable to compare the computed frequency values to those obtained from a current observation time. The 1200 GMT observation value was chosen for comparison, since this is the current local observation time in all four time zones that most nearly represents nighttime conditions. Such a comparison serves two purposes: (1) if percent frequencies from four different local observation times compare favorably to the computed frequency, this supports the hypothesis used for computing the percent values; and (2) additional 1200 GMT inversion frequencies, obtained either from towers or other upper air facilities, may be analyzed for relatively short sampling periods (months) to provide estimates of low-level inversion frequency for a given inland site.

However, since the 1200 GMT observation value was used more often than any other value to compute an inversion frequency, expressed as a percent of total time (i.e., of the available radiosonde data the maximum

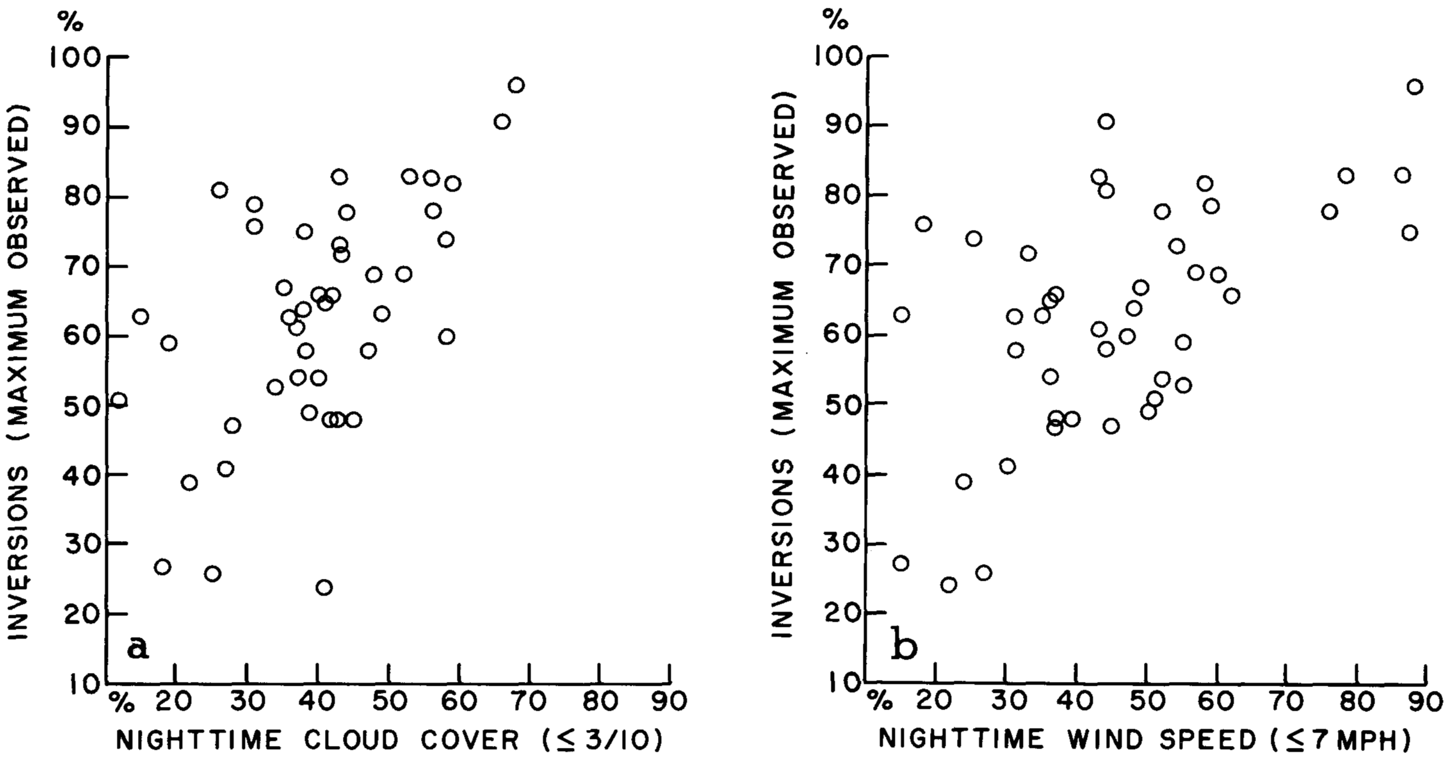


FIGURE 4.—Relationship of maximum observed nighttime inversion percent frequency to (A) nighttime cloud cover ≤ 3/10 and (B) wind speed ≤ 7 m.p.h. Occurrence for winter.

percent value was observed most often at 1200 GMT, in any season, for at least 60 percent of the stations), it was necessary to analyze the unrelated data to justify the selection of the 1200 GMT observation value as being representative of the nocturnal period, for all time zones. This was done for all inland stations by determining the variation of computed frequency, based on the 1200 GMT value, from the computed frequency based on the maximum observed value, for all cases when the maximum value was at an observation time other than 1200 GMT. This comparison showed that for any season the computed frequency determined from the 1200 GMT value, when averaged for all inland stations, differed by less than 3.4 percent from the computed frequency value determined from maximum frequencies at 0000, 0300, or 1500 GMT. On the other hand, since the fraction (nighttime hours)/24, attributed to the length of the nocturnal period is factored into the computed frequency value, it can be estimated that the 1200 GMT frequency value averages about 7 percent less than the maximum value, when the maximum frequency occurs at 0000, 0300, or 1500 GMT. This indicates that of the available radiosonde data analyzed, the 1200 GMT percent value is the most representative of the nocturnal period for all four time zones. Also, it was of interest to note that the 0300 GMT value yields a fairly close approximation of nighttime inversion frequency for fall and winter seasons; however, the 1500 GMT value appears to be unrepresentative of the nighttime period, except for western sections of the country in winter.

The next step was to relate empirically the computed inversion frequency to the currently observed 1200 GMT percent value. This is done in figure 8, which compares the computed percent value on the ordinate (Y) to the 1200 GMT percent value on the abscissa (X). Each point represents a station, and a least square fit provides the regression line. Coastal stations are not included in the regression analysis, but they are designated in the graphs. Their position relative to the regression line may provide an index to continentality. Since the ordinate is determined from the abscissa value for about 60 percent of the cases, no correlations were attempted. However, despite the related data inherent in the statistics, good relevance is indicated. In general, the relationships are sufficiently good to permit use of the 1200 GMT radiosonde data, for inland stations in all time zones, for determining inversion frequencies as a percent of total time.

6. TOWER DATA

Temperatures obtained from meteorological towers and valley-ridge field stations and an instrumented TV tower [1, 2, 4, 6, 7, 8, 10, 12] provide inversion frequency statistics that can be compared to inversion frequencies computed from nearby radiosonde stations. For all nine such stations temperature gradient data are continuously recorded and thereby readily provide frequencies in the form of percent of total hours. These statistics, which can be directly compared to the computed frequencies, are shown in table 6.

TABLE 6.—*Comparison of computed inversion frequency to tower and valley-ridge vertical temperature gradient data*

Station groups	Percent of total hours: Winter	Spring	Summer	Fall	Annual	Period of record	Vertical height (ft.)
Las Vegas, Nev. (radiosonde)	54	39	37	50	45	June 55–May 59	
Yucca Flat, Nev. (valley-ridge)	53	32	38	50	43	January 59–March 60	ΔZ=500
Toledo, Ohio (radiosonde)	23	22	30	36	28	1946–1950	
Enrico Fermi, Mich. (tower)	23	23	34	30	28	December 56–November 59	ΔZ=100–25
Mount Clemens, Mich. (radiosonde)	15	21	26	30	23	February 48–December 50	
Detroit, Mich. (TV tower)	23	23	36	34	30	December 56–November 59	ΔZ=300–20
Albany, N.Y. (radiosonde)	27	29	31	36	31	September 53–August 55	
Middletown, Conn. (tower)	33	23	27	32	29	June 57–May 59 April 56–March 59	ΔZ=200–5
Nashville, Tenn. (radiosonde)	31	27	32	40	33	June 55–May 59	
Greensboro, N.C. (radiosonde)	49	36	36	42	41	June 55–May 59	
Oak Ridge, Tenn. (towers)[1] (valley-ridge)	41	42	46	49	45	1955–1958	
Boise, Idaho (radiosonde)	51	38	36	50	44	June 55–May 59	
Idaho Falls, Idaho (tower)	52	37	45	57	48	January 56–June 58	ΔZ=250–5
Salem-Portland, Oreg. (radiosonde)	32	29	28	38	32	June 56–May 59	
Spokane, Wash. (radiosonde)	37	29	31	40	34	June 56–May 59	
Hanford, Wash. (tower)	45	32	27	42	37	1955–1958	ΔZ=400–50
Omaha, Nebr. (radiosonde)	42	27	33	38	35	June 56–May 59	
Sioux Falls, S. Dak. (valley-ridge) (Pathfinder Site)	37	50	47	37	43	May 58–April 60	ΔZ=154
Pittsburgh, Pa. (radiosonde)	24	31	27	34	29	June 56–May 59	
Shippingport, Pa. (valley-ridge)	14	19	23	28	21	April 55–May 57	ΔZ=400

[1] Average of Tower Shielding Facility (TSF), Melton Valley (MV), and Oak Ridge National Laboratory site (X-10 Sta.): For TSF, ΔZ=300 ft.; above a wooded ridge top, 500 ft. from valley floor; for MV, ΔZ=60 ft.; 5 ft. from the floor of a wooded valley; for X-10, ΔZ=135 ft.; 5 ft. atop a small ridge overlooking an industrial type valley, 90 ft. below.

While most of the towers give vertical temperature gradients within a height interval of less than 500 feet, this is not a serious obstacle for comparing the two sets of data, because nearly all nocturnal inversions (based below 500 feet above the surface) reported by inland radiosonde stations are based below 100 feet above the ground. In fact, most are surface based. The inherent discrepancies involved in differences of (a) periods and lengths of record, (b) geography, and (c) instrumentation are obvious; consequently, it is surprising to find that the frequency values compare so closely. In general, the tower data suggest that the methods of computation for determining inversion frequency from radiosonde data are sufficiently reliable for general climatological analysis.

7. OTHER CONSIDERATIONS

Since most of the Weather Bureau radiosonde stations are located at airports which are at the outskirts of cities, the inversion frequencies for the most part are representative of semi-rural or suburban areas. Consequently, one would expect higher frequencies of nocturnal inversions in the open country; but, lower frequencies for central city areas would be expected because of the mechanical turbulence and heat effects imposed by large metropolitan areas [3]. In the Rocky Mountain and Appalachian regions most of the weather stations are located in valleys; consequently, for these areas the percent values reflect inversion occurrence for elevations lower than the average for the region. Less frequent inversion occurrence would be expected on mountain slopes and tops.

The climatic-synoptic aspects of the west coast, particularly the coastal areas of California and southern Oregon, deserve special attention. The maritime influences and a semipermanent high pressure pattern produce dominating effects. The large-scale subsidence of air at altitudes above the ocean-cooled surface layer results in a stable layer which is semipermanent over the California and Oregon coasts during spring, summer, and fall months. The subsidence inversion acts as a "lid", limiting the vertical motions originating in the marine air below; consequently, it is an important contributor to the gross accumulation of air pollution since the inversion base limits the vertical volume of air in which pollutants may accumulate.

Because the subsidence inversion is often based between 500 and 2000 feet above ground along the coast, it is apparent that the data used in this study (inversion based $\lesssim$ 500 feet above ground) yield very conservative frequency values for the west coast area, relative to any assessment of atmospheric pollution potential for that area. Unlike studies for other areas of the country, a study of the diffusion climatology of the coastal areas of Oregon and California must consider a frequent and persistent occurrence of subsidence inversions based below 2000 feet above the ground, as well as radiation-type inversions based below 500 feet. It is important to note that the present study reflects for the most part only surface-based radiation-type inversions or low-level stability resulting from cool sea breezes. For further details of west coast inversions, the reader is referred to studies by Stanford Research Institute [11] and J. G. Edinger [5].

8. CLIMATIC-GEOGRAPHIC DELINEATION

A review of the distribution of inversion frequency over the country suggests a general delineation into regions according to climatological and geographical factors, and this classification is shown in figure 9. The factors relat-

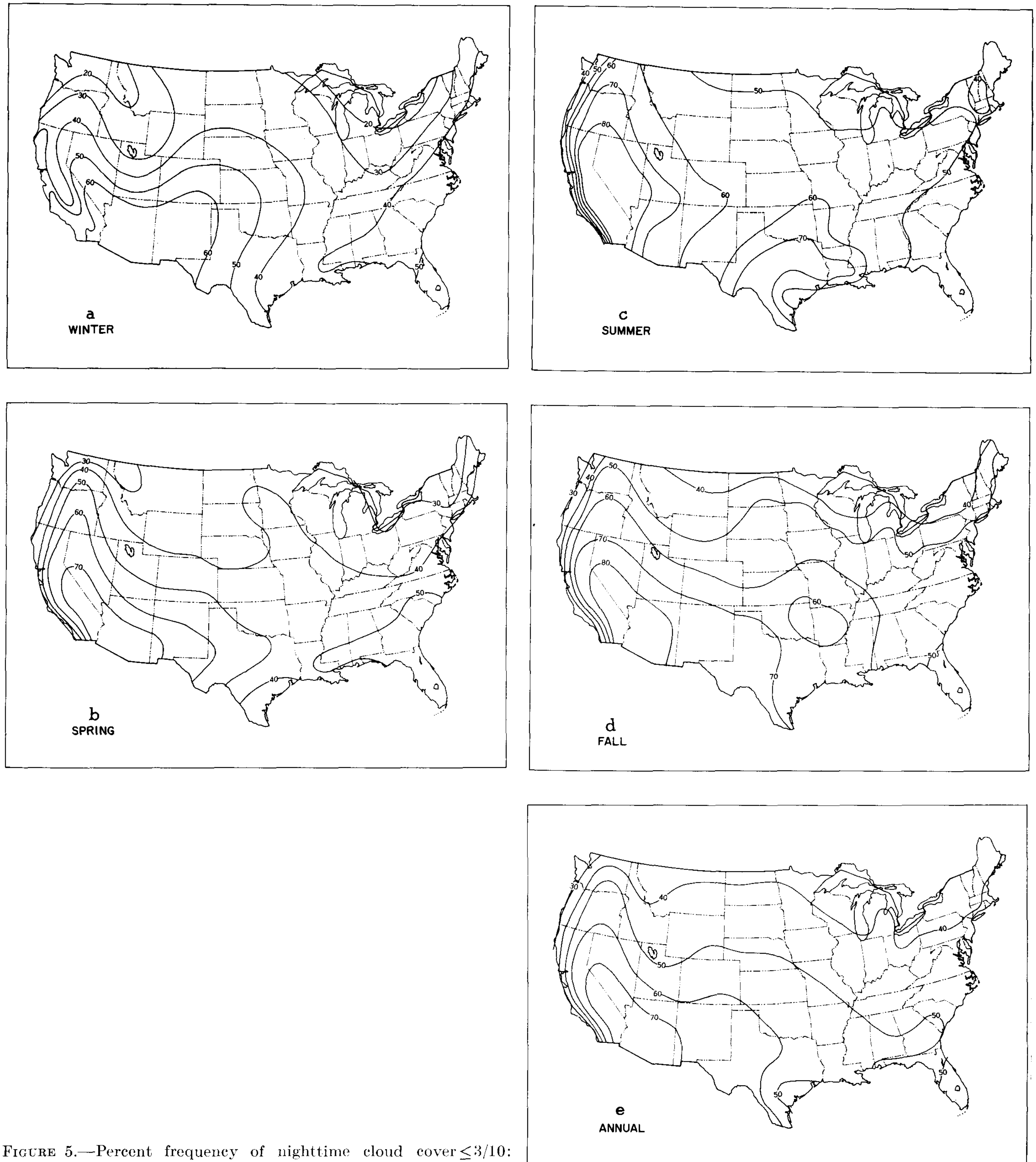
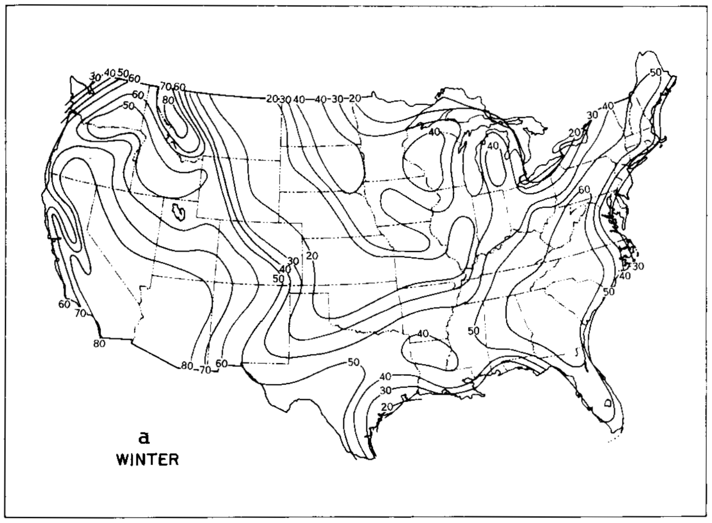
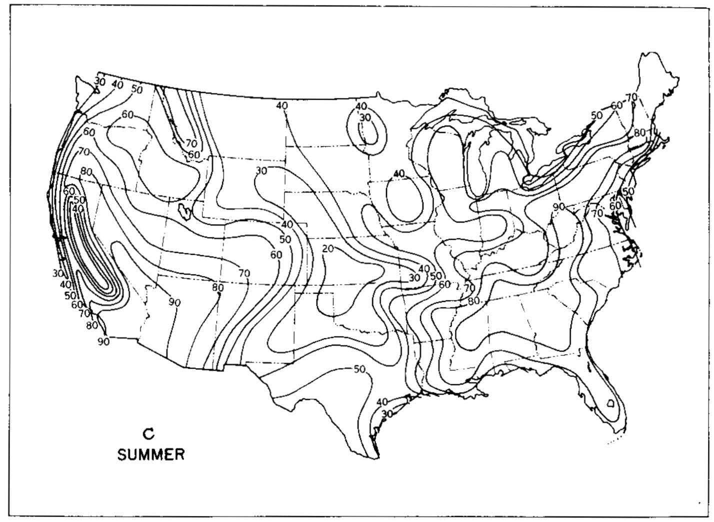
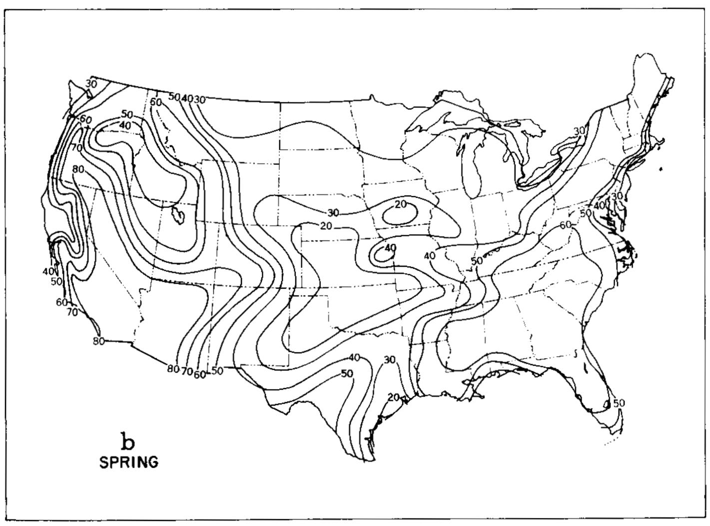
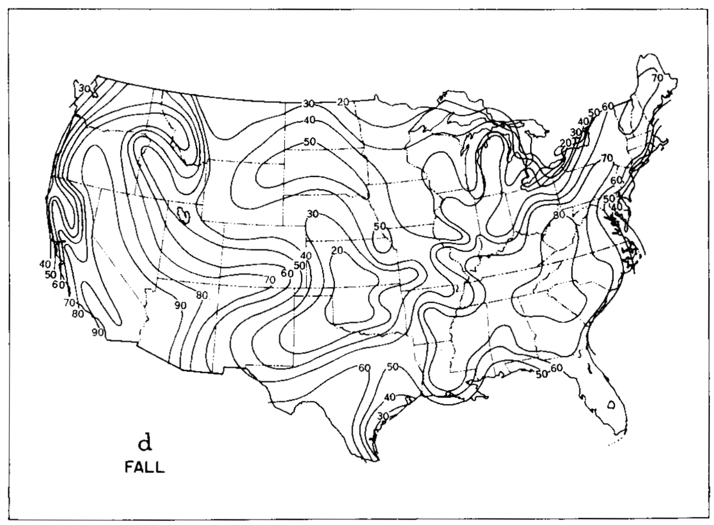


FIGURE 5.—Percent frequency of nighttime cloud cover $\leq 3/10$: (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.









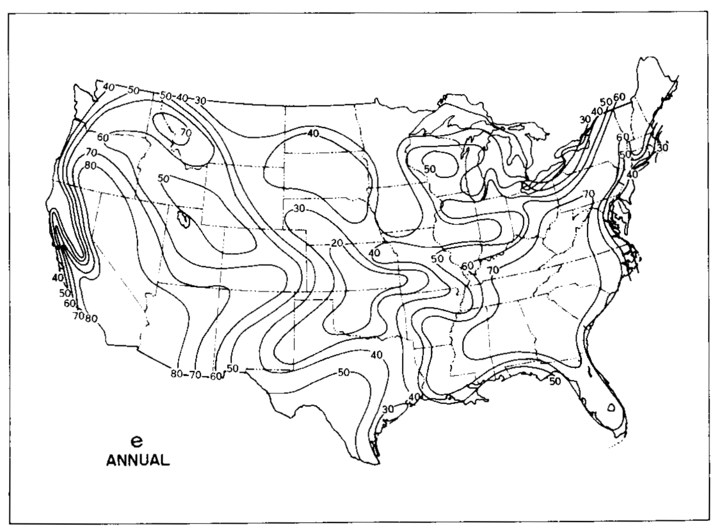
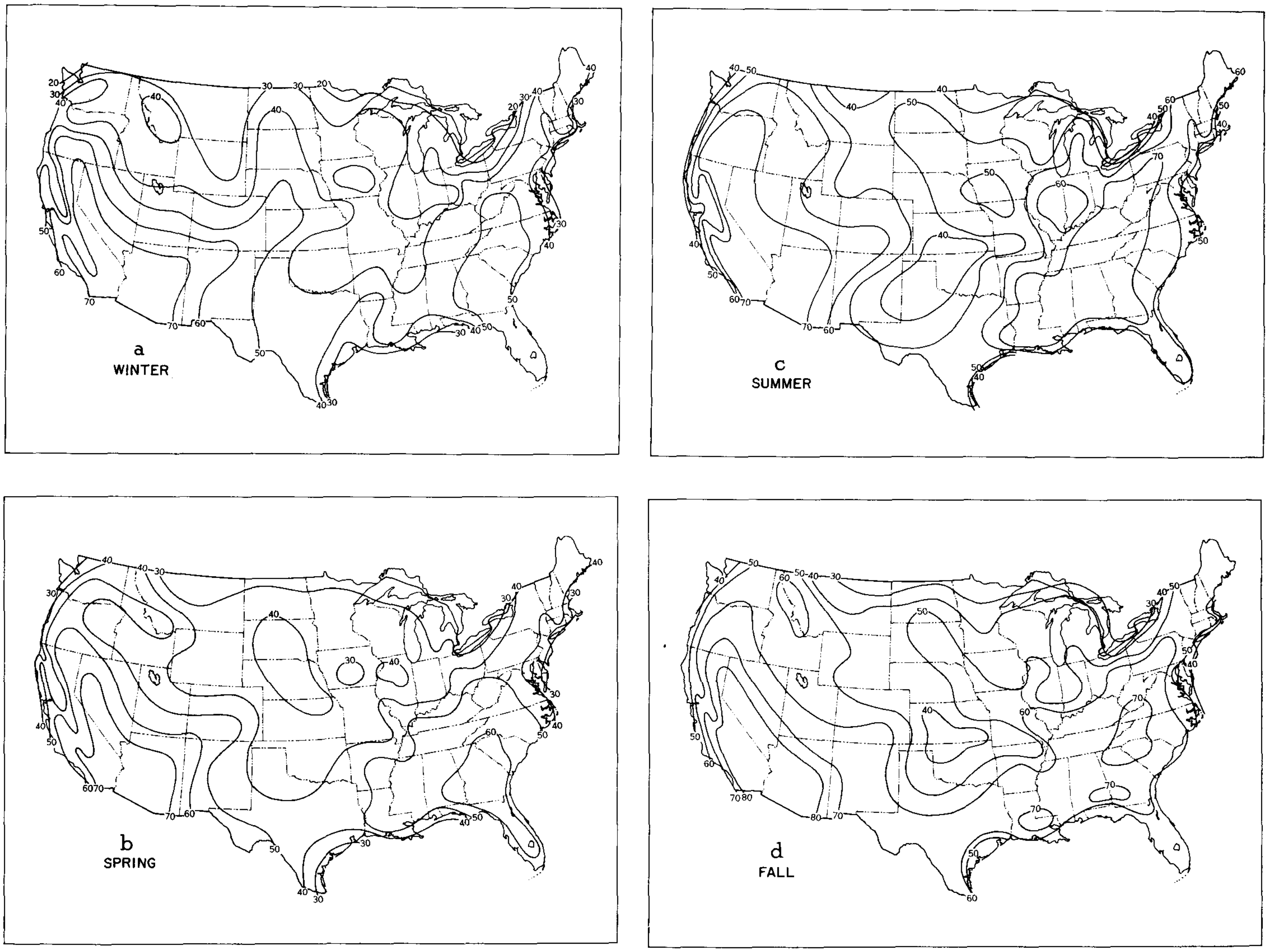


FIGURE 6.—Percent frequency of nighttime wind speed ≤ 7 m.p.h.: (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.



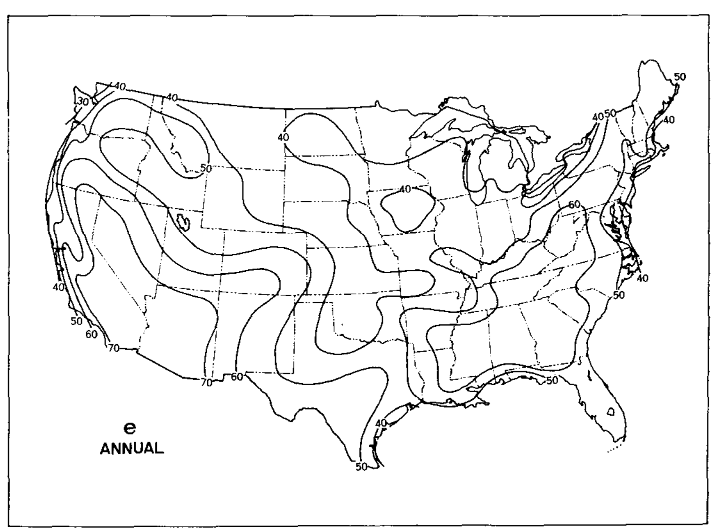


FIGURE 7.—Isopleths of nighttime [(percent cloud cover $\leq 3/10$) + (percent wind speed ≤ 7 m.p.h.)]/2: (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.

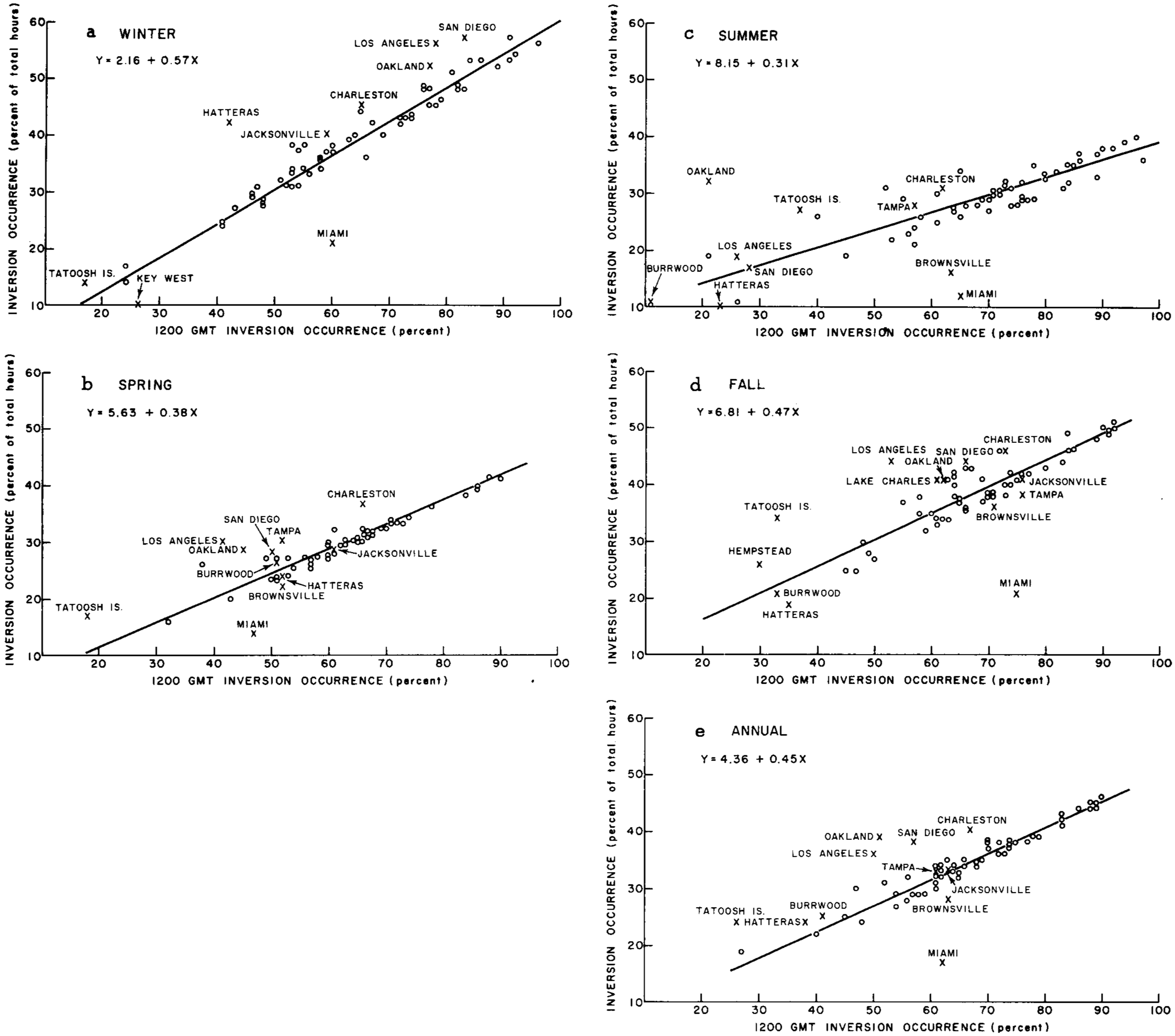


FIGURE 8.—Comparisons of computed inversion frequency (percent of total hours) on the ordinate (Y) to the 1200 GMT observed percent frequency of inversions on the abscissa (X): (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.

ing to inversion occurrence for each region are discussed below.

Great Lakes.—This area is characterized by frequent storm passages with their associated cloudiness and high winds, particularly from late fall to early spring, which result in relatively low frequencies of nocturnal radiation inversions. An analysis of climatological data for specific stations in this area shows a high occurrence of cloudiness during nighttime hours, which apparently reflects the effects of the Great Lakes imparting moisture to the air in its trajectory over the lake water. Summer and fall months show slightly higher frequencies of low-level stability than do the winter and spring months.

Generally, topography plays a small part in this area. However, the western slopes of the Appalachians probably enhance instability in western Pennsylvania and New York when the prevailing west and northwest winds blow. This is particularly true during the winter and spring, and is reflected by the frequent occurrence of snow shower activity in these areas. In summary, inversions based below 500 feet above the surface may be expected to occur about 20 to 30 percent of the time in any season in the Great Lakes area, although higher frequencies can be expected in remote sheltered valleys.

Appalachian Mountains.—Less storm frequency in the Southeastern States, compared to the area north of Vir-

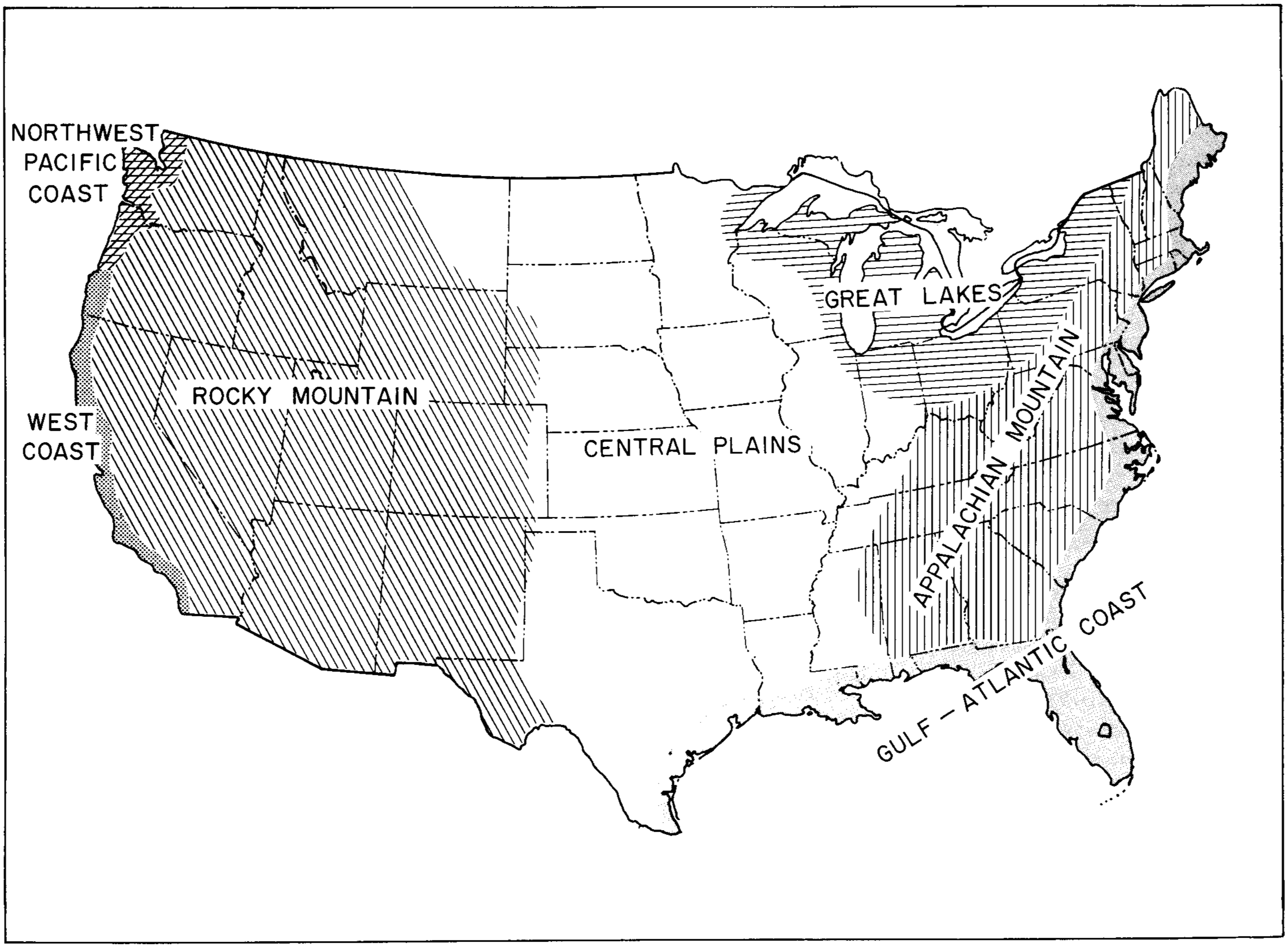


FIGURE 9.—Climatic-geographic delineation of low-level inversion frequency for contiguous United States.

ginia, undoubtedly contributes to the higher inversion frequency found over the southern Appalachian area. Mountain ridges afford protection to valley areas; consequently, light winds during nighttime hours are common in valleys. Frequent occurrence of anticyclonic flow over the Southeastern States, particularly during summer and fall months, also enhances nocturnal radiation inversion formation, since clear skies and light winds are associated with many of these high pressure systems. In general, low-level stabilization occurs 30 to 45 percent of the time in this area, while more topographically protected areas have more frequent occurrences of inversions.

Gulf-Atlantic Coast.—The warm waters of the Gulf of Mexico and Gulf Stream tend to inhibit inversion formation along the immediate coast in these regions. During the warmer months of the year the pressure gradient reinforces the sea breeze over most of the coastal areas of the Gulf of Mexico and Southeastern States. This reinforcement is sufficient to produce relatively strong winds during nights along immediate coastal areas, which helps to delay or inhibit nocturnal radiation inversion formation. Extreme southern Florida depicts minimum continentality, while stations farther inland (e.g., Jacksonville, Lake Charles, Charleston) show higher occurrences of nighttime stability. In general, from Long Island southward along the Atlantic coast to Hatteras, and along the Gulf coast and southern Florida, inversions may be expected 10 to 35 percent of the time. However, higher frequencies are indicated farther inland, as well as for the coastal area between Cape Hatteras and Jacksonville. The higher frequency of low-level stability along the New England coast, reflects the stabilizing effects of cold water off shore.

Central Plains.—The mid-section of the country has a pronounced continental type climate, and as such, has inversion frequencies closely related to the diurnal cycle; that is, there is a definite tendency for nocturnal stabilization and daytime instability in the lower levels. In general, inversions occur 20 to 30 percent of the time during the spring and summer, while during the fall and

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winter months inversions may be expected about 30 to 45 percent of the time. The higher frequency during fall and winter probably is a reflection of minimum storminess in fall and maximum length of a stable nocturnal period in winter. The opposite is true for the spring and summer months. During the colder months, particularly if snow cover exists, warm southerly advection over an existing cold surface may enhance low-level stability in these areas; however, such advection regimes are usually the incipient stages of warm fronts and cyclones with their associated precipitation and storminess, which ultimately produce less stable lapse rates below 500-foot elevations above ground.

Rocky Mountains.—This area also has marked continentality. With the exception of the northern regions during the winter and spring, storms occur infrequently, particularly over the southwestern areas. Unlike the Appalachian regions, dry air prevails most of the time, and inversion frequency is directly related to the diurnal cycle. Radiation inversions form near the surface on most nights, and they are dissipated shortly after sunrise. Since the longest nocturnal stable period and minimum daytime solar heating occur during the winter, it is this season that is potentially the most stable in this area. In general, inversions occur 40 to 55 percent of the time in fall and winter, and about 30 to 40 percent of the time in spring and summer.

West Coast.—Radiation inversions over interior areas, including areas only a few miles from the coast, are most prominent during the late fall and winter months. Along the immediate coast radiation inversions may merge with subsidence inversions, and low-level stability may persist until noon; or, on occasion, inversions persist for several days during which fog often occurs [11]. For the most part, the immediate coast has sufficient surface winds to provide good ventilation; however, the persistence of the subsidence inversion in addition to radiation inversions, the daily reversal of wind direction (land-sea breeze), and topographical sheltering of the valley and basin areas along coastal sections combine to create a potentially adverse climate as far as air pollution is concerned.

Pacific Northwest Coast.—Precipitation, cloudiness, and relatively high winds are dominant features of the climate of Washington and Oregon coastal areas. This region is situated far enough north of the high pressure cell which persists off the California coast to permit most storm systems from the Pacific to pass inland over the area. Consequently, storm activity is frequent, particularly during the winter and early spring. The instability associated with these frequent storm passages results in a relatively low frequency of radiation inversions. Radiation inversions are most frequent during the summer and early fall, when storm activity is at a minimum.

ACKNOWLEDGMENTS

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APPENDIX: CLIMATOLOGICAL DATA

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind ≲7 mph	Nighttime Cloud Cover ≲3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Akron, Ohio	Winter						32	22		
	Spring						45	29		
	Summer						80	52		
	Fall						59	45		
Albany, N.Y.	Winter	47	11	31	43	27	45	28	Rome, N. Y., September 1953–August 1955.	Albany, N.Y., June 1957–May 1959.
	Spring	63	4	15	45	29	52	29		
	Summer	75	1	27	52	31	65	40		
	Fall	60	7	47	66	36	63	40		
Albuquerque, N. Mex.	Winter	67	72	8	82	48	58	59	Albuquerque, N. Mex., June 1955–May 1957.	Albuquerque, N. Mex., June 1957–May 1959.
	Spring	38	24	2	70	32	40	60		
	Summer	29	8	4	71	30	46	54		
	Fall	72	41	2	76	41	48	76		
Allentown, Pa.	Winter						49	36		
	Spring						53	35		
	Summer						79	53		
	Fall						64	48		
Amarillo, Tex.	Winter	71	68	16	74	43	25	58	Amarillo Air Force Base, Tex., June 1955–September 1956; Amarillo Air Terminal, October 1956–May 1957.	Amarillo Air Terminal, Tex., June 1957–May 1959.
	Spring	45	18	4	65	30	15	54		
	Summer	48	10	3	82	34	23	55		
	Fall	71	43	6	70	38	26	71		
Asheville, N.C.	Winter						65	42		
	Spring						66	49		
	Summer						96	49		
	Fall						83	58		
Atlanta, Ga.	Winter	65	31	47	78	38	36	41	Atlanta, Ga., June 1953–May 1955	Athens, Ga., June 1957–May 1959.
	Spring	67	5	17	71	31	41	49		
	Summer	70	2	13	70	29	65	47		
	Fall	70	10	51	75	38	55	55		
Augusta, Ga.	Winter						66	45		
	Spring						68	51		
	Summer						82	48		
	Fall						80	55		
Austin, Tex.	Winter						45	40		
	Spring						43	42		
	Summer						50	65		
	Fall						60	63		
Baltimore, Md.	Winter						36	37		
	Spring						34	40		
	Summer						47	55		
	Fall						42	53		
Baton Rouge, La.	Winter						41	43		
	Spring						54	53		
	Summer						81	71		
	Fall						71	70		
Billings, Mont.	Winter						27	29		
	Spring						35	35		
	Summer						38	55		
	Fall						35	49		
Birmingham, Ala.	Winter						51	38		
	Spring						59	49		
	Summer						86	54		
	Fall						68	57		
Bismarck, N. Dak.	Winter	65	57	37	67	42	49	35	Bismarck, N. Dak., June 1955–May 1957.	Bismarck, N. Dak., June 1957–May 1959.
	Spring	59	19	2	61	28	38	39		
	Summer	77	9	2	77	29	52	51		
	Fall	69	41	15	65	37	49	50		
Boise, Idaho	Winter	79	75	19	81	51	44	26	Boise, Idaho, June 1955–May 1957	Boise, Idaho, June 1957–May 1959.
	Spring	61	59	2	84	38	38	45		
	Summer	68	33	1	97	36	54	68		
	Fall	90	81	8	92	50	46	60		
Boston, Mass.	Winter						17	39		
	Spring						18	35		
	Summer						29	48		
	Fall						23	48		
Brownsville, Tex.	Winter	53	51	7	66	36	37	42	Brownsville, Tex., June 1955–May 1957.	Brownsville, Tex., June 1957–May 1959.
	Spring	21	11	1	52	22	26	32		
	Summer	9	2	2	63	16	45	71		
	Fall	57	23	4	71	36	54	69		
Buffalo, N.Y.	Winter	27	18	17	24	17	15	18	Buffalo, N.Y., June 1955—May 1957	Buffalo, N.Y., June 1957–May 1959.
	Spring	58	4	11	49	27	18	32		
	Summer	70	1	5	58	26	24	44		
	Fall	56	9	20	48	30	19	39		
Burbank, Calif.	Winter						81	59		
	Spring						83	52		
	Summer						85	65		
	Fall						91	68		
Burlington, Iowa	Winter						25	37		
	Spring						30	41		
	Summer						56	57		
	Fall						38	58		
Burrwood, La.	Winter	63	36	46	69	40			Burrwood, La., June 1955–May 1957	Burrwood, La., June 1957–May 1959.
	Spring	57	11	18	51	26				
	Summer	26	1	4	11	11				
	Fall	38	3	13	33	21				
Cape Hatteras, N.C.	Winter	40	3	42	42	42			Hatteras, N.C., June 1955–February 1957; Cape Hatteras, March 1957–May 1957.	Cape Hatteras, N.C., June 1957–Ma 1959.
	Spring	51	6	43	52	24				
	Summer	14	3	11	23	10				
	Fall	29	5	31	35	19				

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind ≲7 mph	Cloud Cover ≲3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Caribou, Maine	Winter	49	27	39	60	38			Caribou, Maine, June 1955–May 1957	Caribou, Maine, June 1957–May 1959.
	Spring	57	7	24	38	26				
	Summer	69	1	27	40	26				
	Fall	52	9	49	49	28				
Charleston, S.C.	Winter	78	23	59	65	45	52	44	Charleston, S.C., June 1955–May 1957	Charleston, S.C., June 1957–May 1959.
	Spring	79	4	23	66	36	57	51		
	Summer	74	2	11	62	31	76	43		
	Fall	85	9	63	73	46	73	51		
Charlotte, N.C.	Winter						69	41		
	Spring						66	46		
	Summer						79	43		
	Fall						74	53		
Chattanooga, Tenn.	Winter						62	35		
	Spring						66	46		
	Summer						91	54		
	Fall						83	53		
Cheyenne, Wyo.	Winter						21	48		
	Spring						27	41		
	Summer						43	58		
	Fall						35	56		
Chicago, Ill.	Winter						29	30		
	Spring						39	36		
	Summer						72	54		
	Fall						47	50		
Cincinnati, Ohio	Winter						31	26		
	Spring						38	36		
	Summer						69	55		
	Fall						50	54		
Cleveland, Ohio	Winter						22	22		
	Spring						38	30		
	Summer						63	54		
	Fall						38	42		
Columbia, Mo.	Winter	53	38	27	52	31			Columbia, Mo. June 1955–May 1957	Columbia, Mo., June 1957–May 1959.
	Spring	52	4	1	67	31				
	Summer	84	5	5	78	35				
	Fall	80	24	20	66	43				
Columbia, S.C.	Winter						68	44		
	Spring						66	51		
	Summer						84	46		
	Fall						83	54		
Columbus, Ohio	Winter						54	25		
	Spring						48	32		
	Summer						86	53		
	Fall						72	50		
Corpus Christi, Tex.	Winter						26	40		
	Spring						26	34		
	Summer						38	66		
	Fall						30	66		
Dallas, Tex.	Winter						44	47		
	Spring						33	50		
	Summer						30	71		
	Fall						51	68		
Dayton, Ohio	Winter	40	21	17	41	24	30	27	Dayton, Ohio, June 1955–May 1957	Dayton, Ohio, June 1957–May 1959.
	Spring	41	6	2	57	26	40	41		
	Summer	57	4	4	66	28	71	57		
	Fall	69	15	31	65	37	50	51		
Denver, Colo.	Winter	82	75	54	83	48	43	53	Denver, Colo., June 1954–May 1956	Denver, Colo., June 1957–May 1959.
	Spring	58	22	5	65	30	47	46		
	Summer	54	15	8	84	35	52	56		
	Fall	78	49	22	80	43	55	62		
Des Moines, Iowa	Winter						20	36		
	Spring						20	40		
	Summer						36	53		
	Fall						29	57		
Detroit, Mich.	Winter						27	25		
	Spring						40	34		
	Summer						63	55		
	Fall						47	49		
Dodge City, Kans.	Winter	78	69	47	77	45			Dodge City, Kans., June 1955–May 1957.	Dodge City, Kans., June 1957–May 1959.
	Spring	52	16	7	67	31				
	Summer	64	8	1	85	35				
	Fall	76	46	28	77	42				
Duluth, Minn.	Winter						25	34		
	Spring						28	37		
	Summer						43	46		
	Fall						26	38		
El Paso, Tex.	Winter	71	91	3	84	53	44	66	El Paso, Tex., June 1955–May 1957	El Paso, Tex., June 1957–May 1959.
	Spring	45	33	2	67	31	34	68		
	Summer	34	11	1	61	25	37	57		
	Fall	76	55	4	69	41	49	75		
Ely, Nev.	Winter	79	91	22	86	53			Ely, Nev., June 1955–May 1957	Ely, Nev., June 1957–May 1959.
	Spring	52	52	0	78	36				
	Summer	63	42	1	96	40				
	Fall	86	89	9	91	49				
Evansville, Ind.	Winter						36	32		
	Spring						44	41		
	Summer						63	57		
	Fall						62	57		
Fargo, N. Dak.	Winter						24	37		
	Spring						21	41		
	Summer						30	52		
	Fall						22	46		

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind ≤7 mph	Cloud Cover ≤3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Flint, Mich	Winter	25	15	28	46	29			Mount Clemens Air Force Base, Mich., June 1954–May 1956.	Flint, Mich., June 1957–May 1959.
	Spring	49	9	4	65	30				
	Summer	72	5	2	70	27				
	Fall	47	10	21	63	34				
Fort Worth, Tex	Winter	58	38	13	55	34			Fort Worth, Tex., June 1955–May 1957.	Fort Worth, Tex., June 1957–May 1959.
	Spring	42	7	2	51	23				
	Summer	45	2	2	53	22				
	Fall	69	27	18	55	37				
Fort Wayne, Ind	Winter						39	25		
	Spring						41	34		
	Summer						75	53		
	Fall						60	50		
Fresno, Calif	Winter						84	39		
	Spring						64	63		
	Summer						48	91		
	Fall						81	73		
Galveston, Tex	Winter						20	35		
	Spring						18	36		
	Summer						22	56		
	Fall						31	63		
Glasgow, Mont	Winter	75	75	56	76	48			Glasgow, Mont., June 1955–May 1957.	Glasgow, Mont., June 1957–May 1959.
	Spring	68	38	7	72	33				
	Summer	50	14	4	84	32				
	Fall	79	53	17	83	44				
Grand Junction, Colo	Winter	81	86	8	91	53			Grand Junction, Colo., June 1955–May 1957.	Grand Junction, Colo., June 1957–May 1959.
	Spring	60	32	0	67	31				
	Summer	67	17	4	90	38				
	Fall	90	75	6	84	49				
Grand Rapids, Mich	Winter						43	20		
	Spring						44	33		
	Summer						76	51		
	Fall						57	45		
Great Falls, Mont	Winter	73	74	41	76	48	18	31	Great Falls, Mont., June 1955–May 1957.	Great Falls, Mont., June 1957–May 1959.
	Spring	32	36	1	68	31	26	32		
	Summer	34	28	2	75	28	32	51		
	Fall	66	70	8	70	38	27	45		
Green Bay, Wis	Winter	54	31	29	53	34			Green Bay, Wis., June 1955–May 1957.	Green Bay, Wis., June 1957–May 1959.
	Spring	58	8	9	71	33				
	Summer	76	9	4	76	29				
	Fall	59	16	22	61	33				
Greensboro, N.C	Winter	73	15	58	72	43	54	43	Greensboro, N.C., June 1955–May 1957.	Greensboro, N.C., June 1957–May 1959.
	Spring	70	3	13	66	32	56	49		
	Summer	78	1	11	66	33	79	48		
	Fall	74	4	52	74	40	68	58		
Harrisburg, Pa	Winter						60	32		
	Spring						54	32		
	Summer						85	52		
	Fall						77	47		
Hartford, Conn	Winter						50	34		
	Spring						54	32		
	Summer						81	39		
	Fall						66	41		
Helena, Mont	Winter						69	26		
	Spring						63	33		
	Summer						67	55		
	Fall						69	48		
Houston, Tex	Winter						22	31		
	Spring						26	39		
	Summer						40	68		
	Fall						34	61		
Indianapolis, Ind	Winter						24	30		
	Spring						29	38		
	Summer						57	57		
	Fall						40	55		
International Falls, Minn	Winter	55	48	12	53	34			International Falls, Minn., June 1955–May 1957.	International Falls, Minn., June, 1957–May 1959.
	Spring	51	15	2	57	26				
	Summer	70	4	2	65	26				
	Fall	45	19	7	47	25				
Jackson, Miss	Winter	54	32	31	58	34	47	38	Jackson, Miss., June 1944–January 1945, February 1956–May 1957.	Jackson, Miss., June 1957–May 1959.
	Spring	59	10	7	60	27	62	49		
	Summer	68	4	11	72	30	83	61		
	Fall	70	24	29	58	38	70	62		
Jacksonville, Fla	Winter	69	27	44	59	40	60	48	USNAS, Jacksonville, Fla., June 1955–October 1955; WBAS, Jacksonville, November 1955–May 1957.	WBAS, Jacksonville, Fla., June 1957–May 1959.
	Spring	53	4	10	61	28	63	54		
	Summer	38	1	11	56	23	75	44		
	Fall	51	12	37	71	41	63	47		
Joilet, Ill	Winter	46	25	29	56	33			Joliet, Ill., March 1951–February 1953.	Peoria, Ill. June 1957–May 1959.
	Spring	63	5	3	63	29				
	Summer	82	7	4	65	34				
	Fall	71	15	39	73	38				
Kansas City, Mo	Winter						39	47		
	Spring						34	43		
	Summer						47	57		
	Fall						47	62		
Key West, Fla	Winter	1	2	6	26	9			Key West (Navy), Fla., June 1955–May 1957.	Key West (Navy), Fla., June 1957–May 1959.
	Spring	1	0	1	4	1				
	Summer	0	0	1	0	<1				
	Fall	1	0	0	1	<1			Data sparse	throughout period.
Knoxville, Tenn	Winter						55	34		
	Spring						57	44		
	Summer						78	50		
	Fall						73	53		

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind ≦7 mph	Cloud Cover ≦3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
LaCrosse, Wis.	Winter						44	32		
	Spring						39	35		
	Summer						66	49		
	Fall						46	48		
LaGuardia, N.Y.	Winter						22	41		
	Spring						28	36		
	Summer						47	48		
	Fall						36	50		
Lake Charles, La.	Winter	61	30	12	58	36	43	37	Lake Charles, La., June 1955–May 1957.	Lake Charles, La., June 1957–May 1959.
	Spring	53	5	3	58	27	56	44		
	Summer	62	3	5	71	30	76	65		
	Fall	75	12	9	61	41	72	63		
Lakehurst, N.J.	Winter	41	17	--	--	24			Lakehurst (Navy), N.J., June 1953–May 1955.	Station closed July 1955.
	Spring	47	2	--	--	22				
	Summer	51	2	--	--	21				
	Fall	59	12	--	--	32				
Lander, Wyo.	Winter	82	90	50	91	57			Lander, Wyo., June 1955–May 1957.	Lander, Wyo., June 1957–May 1959.
	Spring	50	37	3	67	31				
	Summer	63	18	4	89	33				
	Fall	81	59	18	85	46				
Lansing, Mich.	Winter						31	23		
	Spring						24	35		
	Summer						58	57		
	Fall						33	50		
Las Vegas, Nev.	Winter	88	92	2	92	54			Las Vegas, Nev., June 1955–May 1957.	Las Vegas, Nev., June 1957–May 1959.
	Spring	52	54	0	86	39				
	Summer	52	41	1	89	37				
	Fall	92	88	0	90	50				
Little Rock, Ark.	Winter	49	17	32	46	29	50	39	Little Rock, Ark., June 1955–May 1957.	Little Rock, Ark., June 1957–May 1959.
	Spring	60	11	5	51	27	55	48		
	Summer	73	1	7	61	30	83	59		
	Fall	76	9	24	64	42	77	59		
Los Angeles, Calif.	Winter	48	77	27	78	56	76	56	Long Beach, Calif., March 1954–February 1956.	Santa Monica, Calif., June 1957–May 1959.
	Spring	25	31	20	42	30	79	45		
	Summer	24	14	20	26	19	90	41		
	Fall	51	49	32	53	44	90	51		
Louisville, Ky.	Winter						48	36		
	Spring						54	41		
	Summer						83	62		
	Fall						67	59		
Madison, Wis.	Winter						35	33		
	Spring						37	38		
	Summer						65	50		
	Fall						44	50		
Medford, Oreg.	Winter	75	70	16	65	44	87	38	Medford, Oreg., June 1955–May 1957.	Medford, Oreg., June 1957–May 1959.
	Spring	35	40	2	74	34	77	40		
	Summer	13	32	0	80	33	86	64		
	Fall	63	73	6	76	41	87	38		
Memphis, Tenn.	Winter						31	38		
	Spring						39	49		
	Summer						66	59		
	Fall						55	61		
Miami, Fla.	Winter	39	6	29	60	24	47	58	Miami, Fla., June 1955–May 1957.	Miami, Fla., June 1957–May 1959.
	Spring	27	2	10	47	15	49	59		
	Summer	27	2	21	65	13	75	49		
	Fall	41	3	19	75	22	64	48		
Midland, Tex.	Winter	64	67	12	73	43			Midland, Tex., June 1955–May 1957.	Midland, Tex., June 1957–May 1959.
	Spring	40	18	1	65	30				
	Summer	45	2	3	64	27				
	Fall	63	29	8	61	34				
Milwaukee, Wis.	Winter						26	32		
	Spring						33	43		
	Summer						57	51		
	Fall						36	48		
Minneapolis, Minn.	Winter						35	39		
	Spring						30	41		
	Summer						46	54		
	Fall						36	50		
Missoula, Mont.	Winter						81	14		
	Spring						68	29		
	Summer						76	54		
	Fall						86	45		
Mobile, Ala.	Winter						28	37		
	Spring						40	44		
	Summer						67	54		
	Fall						45	58		
Moline, Ill.	Winter						39	37		
	Spring						41	40		
	Summer						68	57		
	Fall						56	54		
Montgomery, Ala.	Winter	66	29	24	55	38	62	40	Maxwell Field, Montgomery, Ala., December 1952–November 1954.	Donnelly Field, Montgomery, Ala. June 1957–May 1959.
	Spring	64	5	4	60	29	73	50		
	Summer	70	6	10	72	30	90	54		
	Fall	77	16	33	64	42	84	56		
Mount Clemens, Mich.	Winter	25	15	28	46	29			Selfridge Air Force Base, Mich., June 1954–May 1956.	Flint, Mich., June 1957–May 1959.
	Spring	49	9	4	65	30				
	Summer	72	5	2	70	27				
	Fall	47	10	21	63	34				
Nantucket, R.I.	Winter	55				32			U.S. Navy Marine Climatic Atlas of the World. (See References.)	
	Spring	65				30				
	Summer	82				34				
	Fall	70				38				

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind <7 mph	Cloud Cover ≲3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Nashville, Tenn	Winter	51	24	35	53	31	55	34	Nashville, Tenn., June 1955–May 1957.	Nashville, Tenn., June 1957–May 1959
	Spring	60	4	8	56	27	68	47		
	Summer	76	1	6	73	32	93	56		
	Fall	74	16	38	64	40	77	59		
Newark, N.J.	Winter						38	41		
	Spring						39	39		
	Summer						61	52		
	Fall						55	52		
New Orleans, La	Winter						42	37		
	Spring						57	45		
	Summer						81	61		
	Fall						61	63		
New York, N.Y	Winter	21	7	18	24	14			Hempstead Air Force Base, N.Y., September 1954–August 1956.	International Airport, N.Y., June 1957–May 1959.
	Spring	36	3	36	32	16				
	Summer	45	1	22	21	19				
	Fall	48	1	24	30	26				
Norfolk, Va	Winter	28	28	40	48	28	37	43	Norfolk, Va., Fleet Weather Central, September 1953–August 1955.	Norfolk, Va., Municipal Airport, June 1957–May 1959.
	Spring	31	8	15	50	23	42	45		
	Summer	21	3	9	45	19	61	50		
	Fall	29	21	30	50	27	52	53		
North Platte, Nebr	Winter	68	63	36	74	43			North Platte, Nebr., June 1955–May 1957.	North Platte, Nebr., June 1957–May 1959.
	Spring	55	18	3	69	32				
	Summer	74	9	4	76	32				
	Fall	79	51	20	67	43				
Oakland, Calif	Winter	66	83	10	77	49	78	43	Oakland, Calif., June 1955–May 1957	Oakland, Calif., June 1957–May 1959.
	Spring	23	35	14	45	29	64	48		
	Summer	29	13	34	21	29	67	40		
	Fall	58	62	15	62	41	81	51		
Ogden, Utah	Winter	77	66	17	79	46			Ogden, Utah, June 1954–May 1956	Salt Lake City, Utah, June 1957–May 1959.
	Spring	63	23	1	73	33				
	Summer	62	28	2	94	39				
	Fall	84	69	3	84	46				
Oklahoma City, Okla	Winter	63	38	33	59	37	15	49	Oklahoma City, Okla., June 1955–May 1957.	Oklahoma City, Okla., June 1957–May 1959.
	Spring	70	15	6	61	32	14	47		
	Summer	88	5	3	86	37	21	60		
	Fall	85	27	16	72	46	19	67		
Omaha, Nebr	Winter	61	57	43	72	42	33	43	Omaha, Nebr., June 1955–May 1957	Omaha, Nebr., June 1957–May 1959.
	Spring	58	23	8	60	27	29	40		
	Summer	70	15	9	80	33	45	50		
	Fall	71	42	22	64	38	44	59		
Philadelphia, Pa	Winter						38	38		
	Spring						39	36		
	Summer						62	49		
	Fall						54	43		
Phoenix, Ariz	Winter	88	92	0	96	56	88	68	Phoenix, Ariz., June 1955–May 1957	Yuma, Ariz., June 1957–May 1959.
	Spring	58	68	0	86	39	83	71		
	Summer	59	38	0	86	36	81	67		
	Fall	95	88	0	92	51	92	82		
Pittsburgh, Pa	Winter	33	24	20	41	24			Pittsburgh, Pa., June 1955–May 1957	Pittsburgh, Pa., June 1957–May 1959.
	Spring	34	6	5	68	31				
	Summer	55	1	4	64	27				
	Fall	56	15	25	62	34				
Pocatello, Idaho	Winter						45	28		
	Spring						42	42		
	Summer						58	66		
	Fall						54	59		
Port Arthur, Tex	Winter						23	38		
	Spring						32	45		
	Summer						72	72		
	Fall						49	67		
Portland, Maine	Winter	53	29	48	64	40	48	38	Portland, Maine, June 1955–May 1957	Portland, Maine, June 1957–May 1959.
	Spring	60	6	48	53	27	56	35		
	Summer	78	4	41	55	29	79	42		
	Fall	70	16	65	71	38	66	46		
Portland, Oreg	Winter	36	41	8	51	32	51	12	Portland, Oreg., June 1954–May 1956	Salem, Oreg., June 1957–May 1959.
	Spring	19	20	1	63	29	71	30		
	Summer	14	3	0	74	28	75	51		
	Fall	49	43	2	71	38	76	35		
Providence, R.I	Winter						40	41		
	Spring						37	37		
	Summer						63	45		
	Fall						54	51		
Pueblo, Colo	Winter						62	60		
	Spring						60	50		
	Summer						68	61		
	Fall						76	68		
Raleigh, N.C	Winter						60	42		
	Spring						60	49		
	Summer						76	45		
	Fall						75	55		
Rapid City, S. Dak	Winter	73	71	49	77	48			Rapid City, S. Dak., June 1955–May 1957.	Rapid City, S. Dak., June 1957–May 1959.
	Spring	64	29	3	66	30				
	Summer	71	11	12	78	29				
	Fall	77	48	19	74	42				
Richmond, Va	Winter						54	44		
	Spring						57	41		
	Summer						76	47		
	Fall						69	53		

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind ≲7 mph	Cloud Cover ≲3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Rochester, N.Y.	Winter						29	17		
	Spring						35	34		
	Summer						61	49		
	Fall						50	39		
Sacramento, Calif.	Winter						51	37		
	Spring						34	65		
	Summer						20	88		
	Fall						52	71		
Salem, Oreg.	Winter	36	41	8	51	32			Portland, Oreg., June 1954–May 1956.	Salem, Oreg., June 1957–May 1959.
	Spring	19	20	1	63	29				
	Summer	14	3	0	74	28				
	Fall	49	43	2	71	38				
Salt Lake City, Utah	Winter	77	66	17	79	46	59	31	Ogden, Utah, June 1954–May 1956.	Salt Lake City, Utah, June 1957–May 1959.
	Spring	63	23	1	73	33	46	43		
	Summer	62	28	2	94	39	40	62		
	Fall	84	69	3	84	46	50	61		
San Antonio, Tex.	Winter	54	34	9	47	31	52	40	San Antonio, Tex., June 1955–May 1957.	San Antonio, Tex., June 1957–May 1959.
	Spring	27	6	2	43	20	43	37		
	Summer	8	0	2	26	11	50	56		
	Fall	46	15	6	45	25	66	58		
San Diego, Calif.	Winter	27	61	22	83	57	86	56	San Diego, Calif., June 1954–May 1956.	San Diego, Calif., June 1957–May 1959.
	Spring	14	22	9	51	28	82	31		
	Summer	8	4	8	28	17	94	27		
	Fall	31	37	17	66	44	94	46		
San Francisco, Calif.	Winter						55	43		
	Spring						32	53		
	Summer						20	54		
	Fall						42	56		
Santa Monica, Calif.	Winter	48	77	27	78	56			Long Beach, Calif., March 1954–February 1956.	Santa Monica, Calif., June 1957–May 1959.
	Spring	25	31	20	42	30				
	Summer	24	14	20	26	19				
	Fall	51	49	32	53	44				
Sault Ste. Marie, Mich.	Winter	48	53	35	58	36			Sault Ste. Marie, Mich., June 1955–May 1957.	Sault Ste. Marie, Mich., June 1957–May 1959.
	Spring	63	29	14	60	29				
	Summer	84	12	12	73	32				
	Fall	55	25	38	66	36				
Savannah, Ga.	Winter						46	47		
	Spring						56	54		
	Summer						69	47		
	Fall						57	54		
Seattle, Wash.	Winter	13	31	24	63	39	31	15	Seattle, Wash., June 1954–May 1956.	Seattle, Wash., June 1957–May 1959.
	Spring	6	30	0	54	25	31	28		
	Summer	3	19	1	57	21	35	44		
	Fall	19	32	9	69	37	38	32		
Shreveport, La.	Winter	52	31	6	54	31	36	37	Barksdale Air Force Base, La., June 1955–December 1955; Municipal Airport, Shreveport, La., January 1956–May 1957.	Municipal Airport, Shreveport, La., June 1957–May 1959.
	Spring	54	10	3	57	26	42	46		
	Summer	66	3	5	68	28	61	64		
	Fall	75	31	10	63	41	59	63		
Sioux City, Iowa	Winter						38	40		
	Spring						38	39		
	Summer						57	56		
	Fall						50	58		
Sioux Falls, S. Dak.	Winter						37	36		
	Spring						34	38		
	Summer						52	50		
	Fall						45	53		
Spokane, Wash.	Winter	53	59	16	54	37	55	19	Spokane, Wash., June 1955–May 1957.	Spokane, Wash., June 1957–May 1959.
	Spring	23	41	0	63	29	57	39		
	Summer	16	26	1	83	31	66	62		
	Fall	57	57	4	73	40	68	47		
Springfield, Ill.	Winter						18	36		
	Spring						27	41		
	Summer						55	60		
	Fall						33	57		
Springfield, Mo.	Winter						17	44		
	Spring						18	45		
	Summer						26	60		
	Fall						23	61		
St. Cloud, Minn.	Winter	57	60	14	53	38			St. Cloud, Minn., June 1955–May 1957.	St. Cloud, Minn., June 1957–May 1959.
	Spring	60	13	1	63	29				
	Summer	76	6	3	76	29				
	Fall	65	25	14	58	35				
St. Louis, Mo.	Winter	63	24			37			1947–51.	
	Spring	60	11			27				
	Summer	82	7			34				
	Fall	81	13			44				
Syracuse, N.Y.	Winter						40	19		
	Spring						47	30		
	Summer						67	46		
	Fall						53	39		
Tampa, Fla.	Winter	69	17	28	60	37	57	52	Tampa, Fla., June 1956–May 1957.	Tampa, Fla., June 1957–May 1959.
	Spring	59	1	7	52	30	61	57		
	Summer	62	8	14	57	28	81	41		
	Fall	63	2	25	76	38	67	46		

APPENDIX—Continued

Station	Season	Percent frequency of— Inversion GMT 03	15	00	12	Total time	Nighttime Surface Wind $\leq$7 mph	Cloud Cover $\leq$3/10	Station and period of record used: Observations at 0300 and 1500 GMT	Observations at 0000 and 1200 GMT
Tatoosh Island, Wash.	Winter	22	15	17	14	17			Tatoosh Island, Wash., June 1955–May 1957.	Tatoosh Island, Wash., June 1957–May 1959.
	Spring	21	15	11	18	17				
	Summer	31	20	19	37	27				
	Fall	35	38	29	33	34				
Toledo, Ohio	Winter	39	14			23	24	22	Toledo, Ohio, June 1946–December 1950.	
	Spring	49	4			22	31	32		
	Summer	73	1			30	63	51		
	Fall	67	5			36	45	49		
Topeka, Kans.	Winter	44	39	16	48	28	39	45	Topeka, Kans., June 1955–May 1957.	Topeka, Kans., June 1957–May 1959.
	Spring	41	13	2	53	24	40	42		
	Summer	53	7	2	69	29	50	56		
	Fall	64	24	11	60	35	50	60		
Tulsa, Okla.	Winter						27	47		
	Spring						28	48		
	Summer						41	60		
	Fall						35	59		
Tucson, Ariz.	Winter	65	83	2	89	52			Davis Monthan Air Force Base, Tucson, Ariz., June 1955–February 1956; Municipal Airport, Tucson, March 1956–May 1957.	Municipal Airport, Tucson, Ariz., June 1957–May 1960 (September 1958–June 1959 06Z & 18Z only).
	Spring	29	61	1	90	41				
	Summer	19	15	4	74	31				
	Fall	77	70	1	89	48				
Washington, D.C.	Winter	44	22	30	48	28	37	43	Washington, D.C., June 1955–May 1957.	Washington, D.C., June 1957–May 1959.
	Spring	42	5	12	51	23	38	38		
	Summer	47	2	5	57	24	58	49		
	Fall	56	8	34	59	32	54	53		
Wichita, Kans.	Winter						19	49		
	Spring						17	45		
	Summer						13	56		
	Fall						13	63		
Winnemucca, Nev.	Winter			6	82	48			Station opened May 1, 1956.	Winnemucca, Nev., June 1957–May 1959.
	Spring			0	88	41				
	Summer			0	92	38				
	Fall			1	91	49				
Yakima, Wash.	Winter						76	26		
	Spring						55	50		
	Summer						49	70		
	Fall						61	55		
Youngstown, Ohio	Winter						28	23		
	Spring						40	33		
	Summer						72	57		
	Fall						49	48		